

CLAIMS

I claim:

1. A method for controlling hourglass deformations of a solid element in finite element analysis, the method comprising:

establishing an initial element coordinate system of the solid element for an initial undeformed geometry of the solid element;

establishing a current element coordinate system of the solid element for a current deformed geometry of the solid element;

calculating a set of initial nodal coordinates of the solid element in the initial element coordinate system;

calculating a set of current nodal coordinates of the solid element in the current element coordinate system;

evaluating a set of hourglass shape vectors of the solid element from the initial nodal coordinates; and

calculating a set of hourglass deformation magnitudes of the solid element from the hourglass shape vectors, the initial nodal coordinates and the current nodal coordinates.

2. The method as recited in claim 1, further comprising:

evaluating a set of generalized hourglass forces from the hourglass deformation magnitudes, the initial nodal coordinates, and material constants of the solid element.

calculating a set of nodal forces in the current element coordinate system from the generalized hourglass forces and the hourglass shape vectors;

transforming the set of nodal forces from the current element coordinate system to global coordinate system before adding to global force array.

3. The method as recited in claim 1, further comprising:

calculating all terms of an element stabilization matrix for the solid element from the hourglass shape vectors, the initial nodal coordinates, and material constants of the solid element.

4. The method as recited in claim 3, further comprising:

transforming the stabilization matrix from the initial element coordinate system to global coordinate system before adding the terms of the stabilization matrix into global stiffness matrix.

5. The method as recited in claim 1, wherein the solid element is chosen from the group consisting of three-dimensional 8-node hexahedral element, 6-node three-dimensional pentahedral element, two-dimensional 4-node plane strain element and two-dimensional 4-node axisymmetric continuum element.

6. A software product to be executable in a computing device for controlling hourglass deformations of a solid element in finite element analysis, the software product comprising:

program code for establishing an initial element coordinate system of the solid element for an initial undeformed geometry of the solid element;

program code for establishing a current element coordinate system of the solid element for a current deformed geometry of the solid element;

program code for calculating a set of initial nodal coordinates of the solid element in the initial element coordinate system;

program code for calculating a set of current nodal coordinates of the solid element in the current element coordinate system;

program code for evaluating a set of hourglass shape vectors of the solid element from the initial nodal coordinates; and

program code for calculating a set of hourglass deformation magnitudes of the solid element from the hourglass shape vectors, the initial nodal coordinates and the current nodal coordinates.

7. The software product as recited in claim 6, further comprising:

program code for evaluating a set of generalized hourglass forces from the hourglass deformation magnitudes, the initial nodal coordinates, and material constants of the solid element.

program code for calculating a set of nodal forces in the current element coordinate system from the generalized hourglass forces and the hourglass shape vectors;

program code for transforming the set of nodal forces from the current element coordinate system to global coordinate system before adding to global force array.

8. The software product as recited in claim 6, further comprising:

program code for calculating all terms of an element stabilization matrix for the solid element from the hourglass shape vectors, the initial nodal coordinates, and material constants of the solid element.

9. The software product as recited in claim 8, further comprising:

program code for transforming the stabilization matrix from the initial element coordinate system to global coordinate system before adding the terms of the stabilization matrix into global stiffness matrix.

10. The software product as recited in claim 6, wherein the solid element is chosen from the group consisting of three-dimensional 8-node hexahedral element, 6-node three-dimensional pentahedral element, two-dimensional 4-node plane strain element and two-dimensional 4-node axisymmetric continuum element.

11. A machine-readable medium embodying instructions for execution by a processor, the instructions, when executed by the processor, causing the processor to perform a method for controlling hourglass deformations of a solid element in finite element analysis, the method comprising:

establishing an initial element coordinate system of the solid element for an initial undeformed geometry of the solid element;

establishing a current element coordinate system of the solid element for a current deformed geometry of the solid element;

calculating a set of initial nodal coordinates of the solid element in the initial element coordinate system;

calculating a set of current nodal coordinates of the solid element in the current element coordinate system;

evaluating a set of hourglass shape vectors of the solid element from the initial nodal coordinates; and

calculating a set of hourglass deformation magnitudes of the solid element from the hourglass shape vectors, the initial nodal coordinates and the current nodal coordinates.

12. The machine-readable medium as recited in claim 11 further embodying instructions for execution by a processor, the instructions, when executed by the processor, causing the processor to perform a method for controlling hourglass deformations of a solid element in finite element analysis, the method further comprising:

evaluating a set of generalized hourglass forces from the hourglass deformation magnitudes, the initial nodal coordinates, and material constants of the solid element.

calculating a set of nodal forces in the current element coordinate system from the generalized hourglass forces and the hourglass shape vectors;

transforming the set of nodal forces from the current element coordinate system to global coordinate system before adding to global force array.

13. The machine-readable medium as recited in claim 11 further embodying instructions for execution by a processor, the instructions, when executed by the processor, causing the processor to perform a method for controlling hourglass deformations of a solid element in finite element analysis, the method further comprising:

calculating all terms of an element stabilization matrix for the solid element from the hourglass shape vectors, the initial nodal coordinates, and material constants of the solid element.

14. The machine-readable medium as recited in claim 13 further embodying instructions for execution by a processor, the instructions, when executed by the processor, causing the processor to perform a method for controlling hourglass deformations of a solid element in finite element analysis, the method further comprising:

transforming the stabilization matrix from the initial element coordinate system to global coordinate system before adding the terms of the stabilization matrix into global stiffness matrix.

15. The machine-readable medium as recited in claim 11, wherein the solid element is chosen from the group consisting of three-dimensional 8-node hexahedral element, 6-node three-dimensional pentahedral element, two-dimensional 4-node plane strain element and two-dimensional 4-node axisymmetric continuum element.